TUBE-BUILDING CERCOPIDS (HOMOPTERA, MACHAEROTIDAE)

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The Cercopoidea or "Frog-Hoppers" are a small and distinct group of plant-bugs which are poorly represented in Australia; Tillyard (1926) records only thirty species as having been described from this region, but doubtless many more occur.

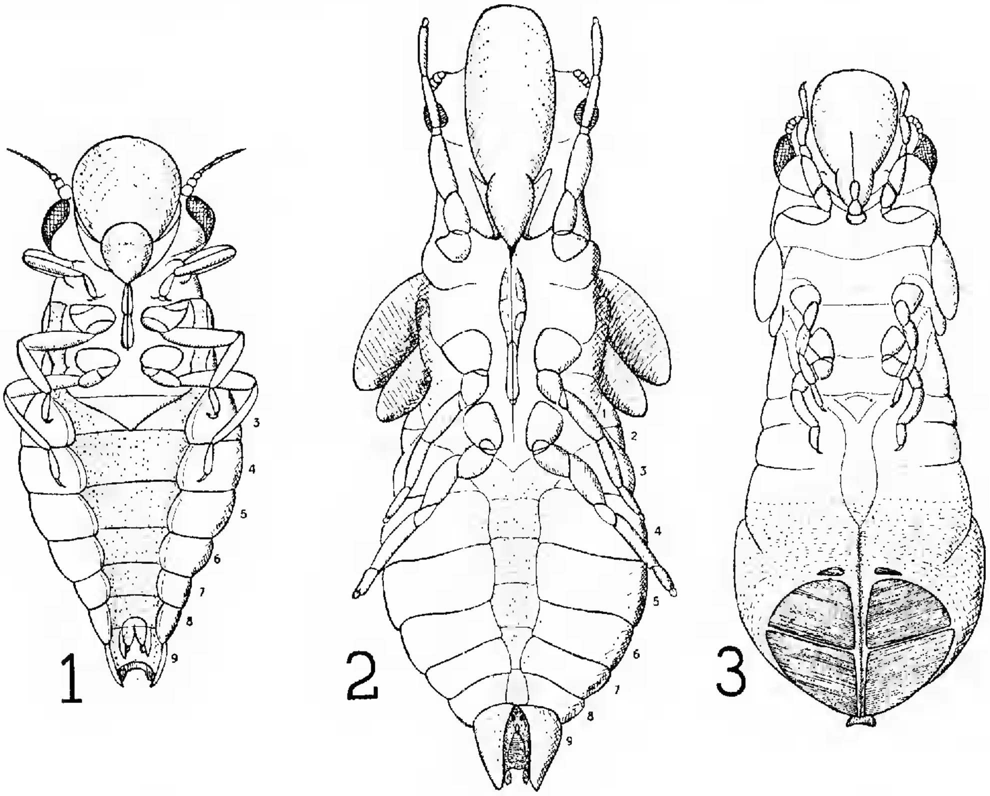
The super-family comprises four families, the Aphrophoridae, Cercopidae, Clastoperidae and the Machaerotidae. Nymphs of insects belonging to the three first-named families make and live in froth masses and are commonly known as "spittle insects," those of the Aphrophoridae and Clastoperidae living above ground, whilst nymphs of the Cercopidae are subterranean.

The Machaerotidae occur only in Australia, Malaya, the Phillipines, India and Africa, and have nymphs which construct calcareous tubes on their food-plants, in which they live head downwards immersed in excreted liquid. Baker (1927) has divided the family into two sub-families, the Machaerotinae and Hindoliinae. Representatives of both occur in Australia but the Hindoliinae are by far the more abundant, anyhow, in Eastern Australia.

The earliest recorded observations of these tube-forming insects are those of Ratte (1884), who described and figured three types of tubes which he found in the neighbourhood of Sydney. He noted the fact that two kinds of nymphs occurred, one being provided with a broad circular plate at the end of the abdomen, whilst the other lacked such a plate. Two years later Westwood (1886) described the adult of a tube-forming frog-hopper from Ceylon, giving it the name of *Machaerota guttigera*. His correspondent in Ceylon, Mr. S. Green, found the nymphs on the Suriya Tulip tree *(Adamsonia digitata)*, and wrote that the insects in the tubes seemed to be continually working the tips of their abdomens against and around the inside of the tubes, discharging at intervals clear liquid from their intestines; also, that when some of the liquid was allowed to dry on a piece of glass, practically no residue was left.

In 1906 Kirkaldy described two species from Australia and figured the nymph of one of them, *Polychaetophyes serpulida* Kirk. He drew attention to the operculum on the abdomen of nymphs of this species, and was of the opinion that it consisted of the second and third tergites. Later illustrations of nymphs or their tubes are given by Lefroy (1909), Hacker (1922), China (1927, 35), and Evans (1935). Hacker's are the most notable, as they consist of remarkable photos showing the emergence of adults of two species from their nymphal quarters. It may be seen from these photos that the nymphs of one species, *Polychaetophyes serpulida* have opercula, whilst those of the other *Pectinariophyes pectinaria* Kirk. lack them.

The purpose of the present paper is to describe and illustrate in greater detail than has previously been done the two types of Machaerotid nymphs, and to compare them with those of the Aphrophoridae.



Figs 1-3

Fig. 1, Nymph of *Bathylus albicincta* (Aphrophoridae) in ventral aspect.
Figs. 2 and 3, Machaerotid nymphs in ventral aspect.

Morphology

In fig. 1 is shown a nymph of *Bathylus albicincta* Erichs. (Aphrophoridae), in ventral aspect, as representative of the type of spittle-forming nymphs. A detailed account of the morphology of nymphs of species belonging to this family has been given by Sulc (1911), and a popular account of the method of froth-formation by China (1927).

There is a deep channel on the ventral surface of the body which extends from the apex of the abdomen, anteriorly as far as the third abdominal segment, where it branches into two, terminating on each side of the body at the anterior margin of the mesothorax. The ventral surface of the channel consists of the abdominal sterna, and its walls of the pleura internally and the overlapping terga externally. The spiracles of each segment open between the sterna and pleura, whilst a very large trachea connects with a spiracle on each side of the hind margin of the prothorax.

In the figure the channel is shown open, but it can be closed by the bringing together of the tergal-pleural flaps which overlap above it. During froth-formation it is closed, and air is drawn into it at the apex of the abdomen. The manner in which these insects form their froth is too well known to need repetition.

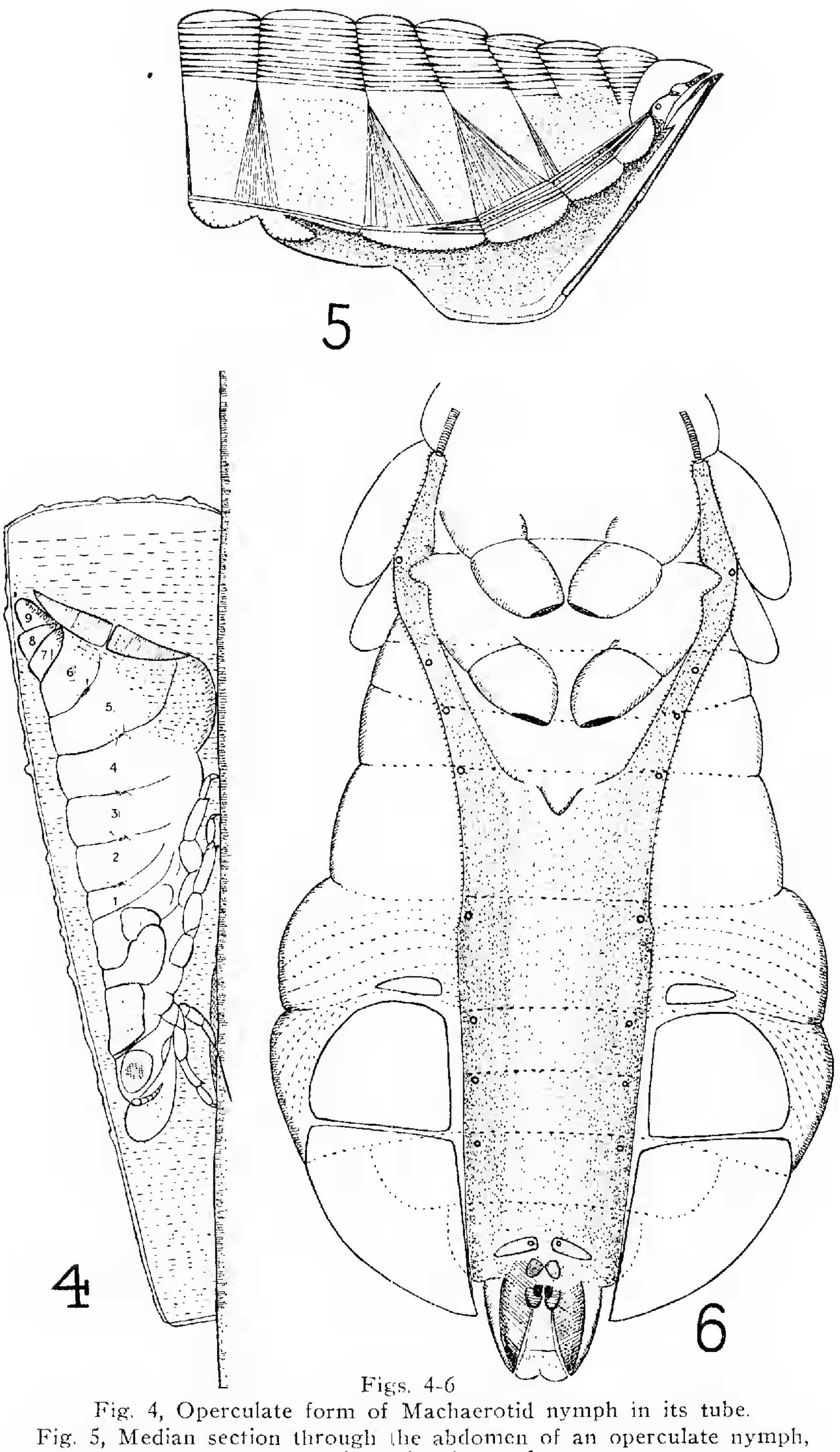
A Machaerotid nymph of the non-operculate type, of which the specific identity is unknown, is illustrated in fig. 2. It resembles the nymph figured under the name of *Pectinariophyes pectinaria* by Kirkaldy, hence probably belongs to the genus *Hindola* Stål, of which *Pectinariophyes* Kirk. is stated by Baker (1927) to be a synonym. The head differs from that of *B. albicincta* in the elongation of the fronto-clypeus and in the comparatively longer labium and maxillary and mandibular stylets. Also the antennae, instead of being freely movable, lie closely opposed to the side of the head, directed posteriorly, suggesting those of a pupa of a holometabolous insect. Only a portion of the eye is pigmented and the legs are flattened against the body; the fore legs being directed anteriorly and the other two pairs posteriorly.

The ventral air channel, which is of the same extent as with the Aphrophoridae, instead of being temporarily closed by overlapping tergal and pleural abdominal flaps, is permanently closed, except at the apex of the abdomen, by a transparent membrane which joins the ventral edges of the terga.

Figure 3 represents a nymph of the operculate type, probably of *Chaetophyes compacta* (Walk.). Another representative of the same species is shown in position in its tube in fig. 4. The operculum, which is formed from the ventral surface of the terga of the fourth, fifth and sixth abdominal segments, consists of three pairs of sclerotized plates. The pair belonging to the fourth segment is small, but this segment is larger and more distorted than the others and forms a "heel." The plates of the sixth segment overlap and conceal the three free abdominal segments. The air canal is identical in structure with that of the type of non-operculate nymph already described from its anterior branches as far as the middle of the fourth abdominal segment. Posteriorly, it is concealed, as the terga from the opposite sides of the body are joined along the mid-ventral line.

Figure 5 is a diagram of a section through the centre of a nymph and shows the air canal, which is widest in the heel of the fourth segment. Three sets of muscle fibres are indicated in the figure. These are the dorsal longitudinal tergal muscles, the ventral longitudinal sternal muscles, and the fan-shaped tergo-sternal muscles, which arise from the lateral walls of the abdomen. The points of insertion of the latter are visible externally as pits (see fig. 4).

In fig. 6 the air canal has been fully exposed by cutting the insect down the mid-ventral line and pulling apart the severed sides. There are eight pairs of abdominal spiracles; the pair belonging to the eighth sternite are close to the middle of the sclerite and not near the anterior border as in other segments. One pair of thoracic spiracles lie at the base of the hind wing-pads, the other pair are at the anterior ends of the canal and connect with very large tracheae.



Figs. 4-6

Fig. 4, Operculate form of Machaerotid nymph in its tube.
Fig. 5, Median section through the abdomen of an operculate nymph, to show the air canal.
Fig. 6, Ventral view of a tube-forming nymph with the air canal exposed.

Tube Formation

Observations made on the early stages of tube-formation by Green, and reported by Westwood, refer to the nymphs of *Machaerota guttigera* Westw. Green observed newly-hatched nymphs in the middle of drops of froth, from which the walls of the tubes gradually arose. Froth is again formed prior to the final ecdysis as recorded by Ratte and Hacker, and it is probably produced at the end of each instar, since the insects have to emerge from their tubes in order to cast their skins. It is thus evident that the liquid excreted by the young hoppers has, like that produced by spittle insects, the properties of a soap solution. Ratte found the tubes to be composed of at least 75% calcium carbonate and considered the insoluble remains to be "chitinous matter," and Professor R. A. Peters who examined some tubes made by the nymphs of an African species, *Aphrosiphon bauhiniae* China (China, 1935), found that they contained 81·3% calcium carbonate. Dr. W. A. Lamborn, who first discovered this particular species, stated that the fluid excreted by the insects was rich in mineral matter which rapidly solidifies. Whenever liquid has been collected from tubes by the present writer, and allowed to dry on a glass slide, no deposit has been left after evaporation. The tops of tubes containing living nymphs are usually soft, whilst the first-formed parts appear to be of a different consistency from the rest, resembling hardened froth.

The nymphs of Aphrophoridae have two pairs of glands, known as Batellis Glands. These lie in the seventh and eighth abdominal segments and secrete a wax-like substance through external pores. Tube-dwelling nymphs have a pair of round yellow glands in each of the sixth, seventh and eighth abdominal segments. These are doubtless homologous with Batellis glands. They have as well a large paired gland, the pseudovitellus, which lies on each side of the fifth abdominal segment.

The nymphs that have been found in Tasmania during the winter months have been in their early instars, and immersed in fluid, but on the New South Wales highlands completely dry tubes have been found in the winter, closed at the top by a membrane and containing nymphs in the pre-imaginal instar. This suggests that development may cease during the cold weather and the last instar be prolonged. At all seasons tubes are occasionally found containing no liquid and tightly closed by the insect's opercula, but the usual condition is for the insect to be totally immersed in its secretory and excretory products.

If a tube is heated, the apical segment of the contained insect is at once protruded, the stale air expelled and a fresh supply taken in. Nymphs in tubes which were subjected to a temperature of 82° F. were found to protrude their abdomens into the air for intervals of five seconds, and then to withdraw them below the surface of the liquid for periods of ten seconds. If kept forcibly emerged for periods ranging from forty-five to ninety seconds, they will withdraw their stylets from the wood and back completely out of the tubes.

Discussion

Amongst many groups of insects, structural adaptations correlated with life in specialized environments are of common occurrence, but this is not so with the Homoptera-Auchenorhyncha. Tube-dwelling nymphs belonging to the Machaerotidae are especially remarkable, since not only have they themselves created an environment of a specialized nature, but they have developed unique structural modifications to cope with their acquired environment. Wax production is of frequent occurrence amongst the Homoptera, and it is possible that the plates of the operculum are modified wax plates. Tufts of wax have been seen on the ventral surfaces of both the seventh and eighth abdominal segments of operculate and non-operculate nymphs.

It is of interest to note that the nymphs of cicadas, many cixiids and certain cercopids, are subterranean. This may well be a primitive characteristic, possibly associated with severe weather conditions that ruled for a long time at some period of geological history, in areas where the forerunners of the present-day representatives existed. A root-feeding insect is not subject to such intense evaporation from its body-surface as is one that feeds above ground, and it is probable that the spittle-forming habits of the nymphs of the Aphrophoridae, and the tube-forming habits of the nymphs of the Machaerotidae are parallel developments, both serving to prevent excessive loss of body-moisture from organisms descended from subterranean ancestors. It is doubtful whether either froth or tube formation serve to any great extent for protective purposes against insect parasites and predators.

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